



# WIDEBAND DIGITAL SIGNAL PROCESSING TEST-BED FOR RADIOMETRIC RFI MITIGATION

DAMON C. BRADLEY, ADAM J. SCHOENWALD, MARK WONG, PRISCILLA N. MOHAMMED\*, JEFFREY R. PIEPMEIER  
NASA GODDARD SPACE FLIGHT CENTER, \*MORGAN STATE UNIVERSITY



## PROBLEM DESCRIPTION

Radio Frequency Interference (RFI) is a persistent and growing problem experienced by spaceborne microwave radiometers. Recent missions such as SMOS, SMAP, and GPM have detected RFI in L, C, X, and K bands [1, 2]. To proactively deal with this issue, microwave radiometers must:

- Utilize new algorithms for RFI detection
- Utilize fast digital back-ends that sample at hundreds of MHz

The wideband digital signal processing testbed (WB-RFI) is a platform that allows rapid development and testing various RFI detection and mitigation algorithms.

## INTRODUCTION

- The WB-RFI system is based on UC Berkeley's Collaboration for Astronomy Signal Processing and Electronics Research (CASPER) (ROACH-2) (Reconfigurable Open Architecture Computing Hardware) FPGA-based signal processor.
- The SMAP Radiometer Digital Electronics (RDE-DSP) was emulated on WB-RFI. We then improved it by scaling the operational sample rate and adding the **complex signal kurtosis algorithm** (CSK) [4] in lieu of the real signal kurtosis for RFI detection.



Figure 7: CASPER-ROACH2 Hardware.

## ACKNOWLEDGEMENT

The research team would like to thank the NASA Earth Science Technology Office NNH13ZDA001N-ACT program for funding this research.

## WIDEBAND RADIOMETER DSP

The WB-RFI system was configured as a polarimetric radiometer back-end processor similar to the SMAP RDE [3]. Each polarization channel signal was downconverted to a complex baseband (I/Q) representation, motivating the use for the CSK algorithm. Like SMAP, the radiometer band was split into frequency subbands, but the CSK was applied to each band  $\ell$ .

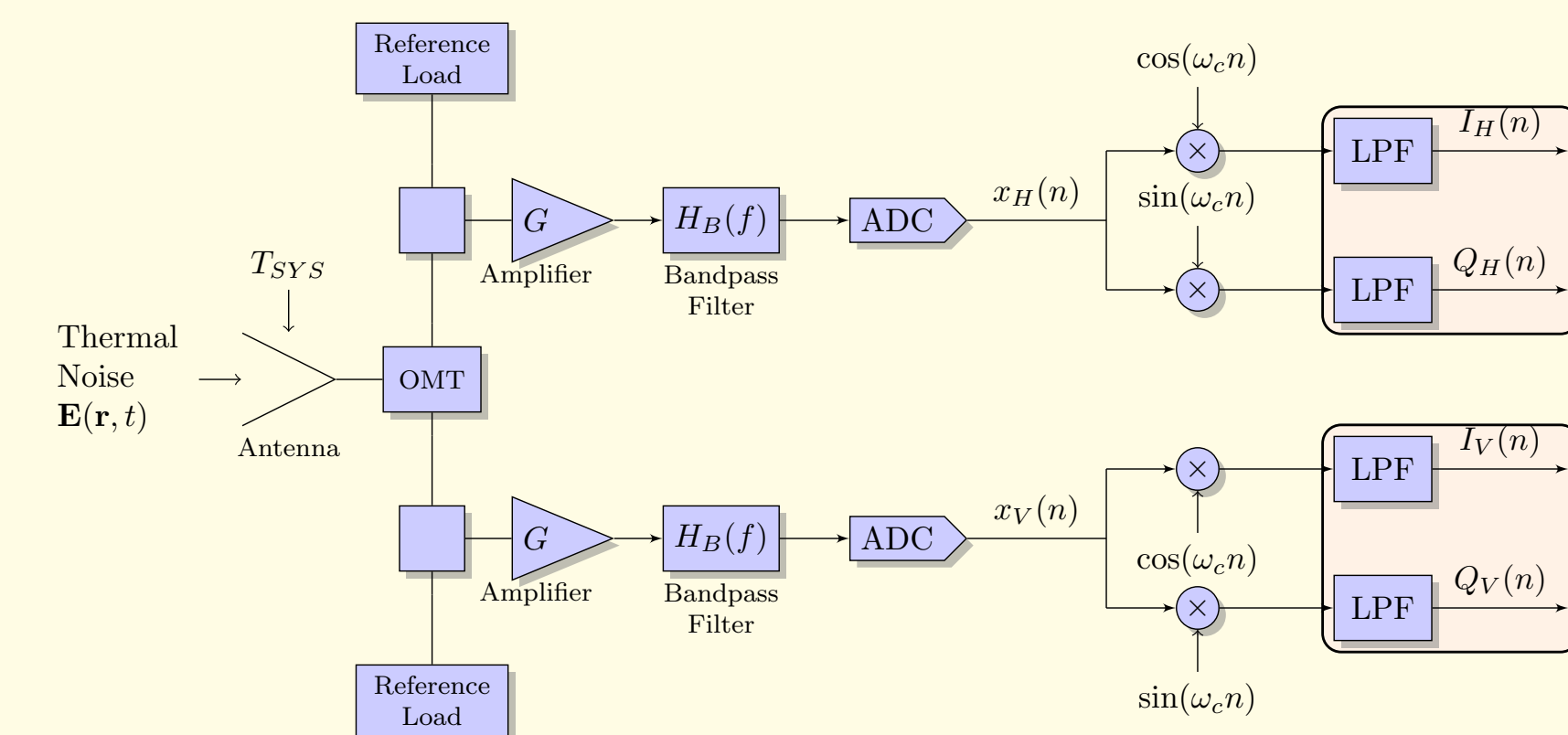


Figure 1: Polarimetric radiometer configuration with identical processing channels for horizontal and vertical polarizations.

## COMPLEX SIGNAL KURTOSIS

Consider the complex baseband signal

$$z(n) = I(n) + jQ(n). \quad (1)$$

Its moments  $\alpha_{\ell,m}$  are defined by

$$\alpha_{\ell,m} = \mathbb{E} [(z - \mathbb{E}[z])^\ell (z - \mathbb{E}[z])^{*m}], \quad \ell, m \in \mathbb{Z}_{\geq 0}, \quad (2)$$

where  $\mathbb{E}$  is the expectation operator and  $*$  is the complex conjugate. *Standardized moments* are defined by

$$\varrho_{\ell,m} = \frac{\alpha_{\ell,m}}{\sigma^{\ell+m}}, \quad (3)$$

where  $\sigma^2 = \alpha_{1,1}$ . The complex signal kurtosis is given by  $\varrho_{2,2} - 2 - |\varrho_{2,0}|^2$  and is used to make the RFI test-statistic  $C_K$

$$C_K = \frac{\varrho_{2,2} - 2 - |\varrho_{2,0}|^2}{1 + \frac{1}{2}|\varrho_{2,0}|^2}. \quad (4)$$

If  $z(n)$  is Gaussian, then  $C_K = 0$ . Otherwise,  $C_K$  is nonzero. Therefore  $C_K$  is a test statistic for non-Gaussianity that can be used for RFI detection. We implemented (4) on the WB-RFI system.

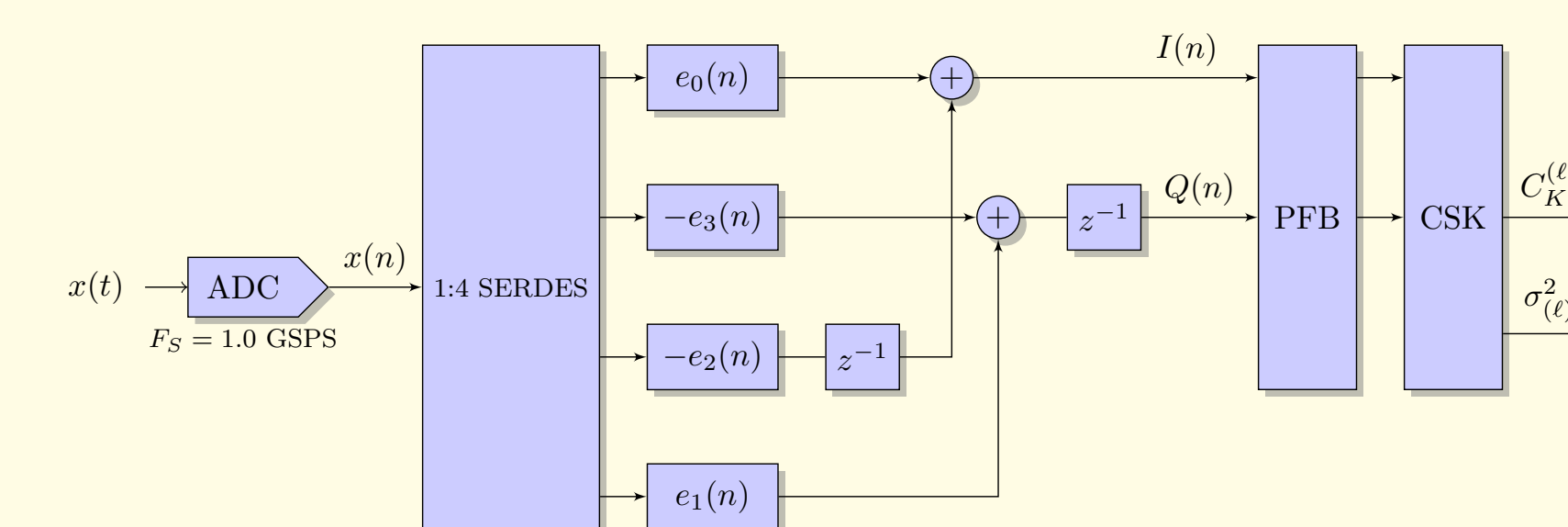


Figure 2: Single-Channel Implementation for 200 MHz bandwidth K-band radiometer. The 200 MHz band was downconverted using a SERDES-polyphase FIR filter that combined mixing, image rejection, and downsampling into polyphase partition filters  $e_k(n)$ .

## PERFORMANCE RESULTS

The CSK was evaluated for continuous and pulsed (Figures 3 & 4) RFI+noise signals as a function of SNR to characterize its receiver operating characteristic (ROC) performance, and compared to the average kurtosis of I and Q components. The system linearity and subband performance were tested in addition (Figures 5 & 6) using bandlimited noise.

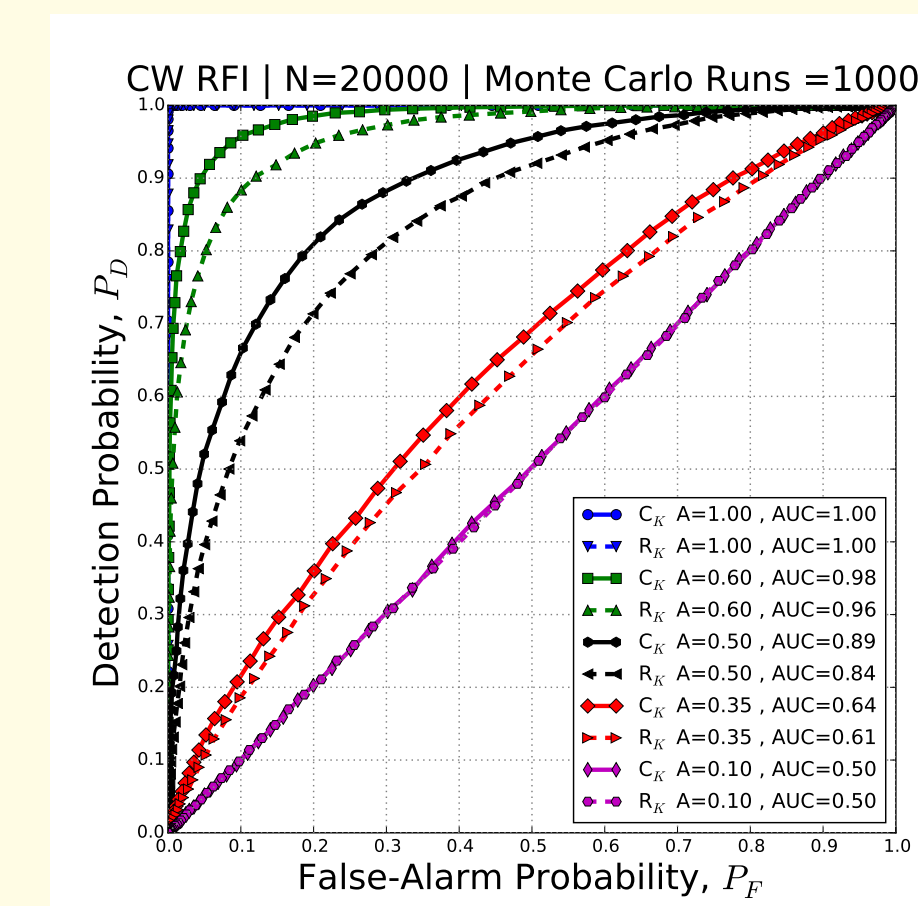


Figure 3: ROC: CW-RFI

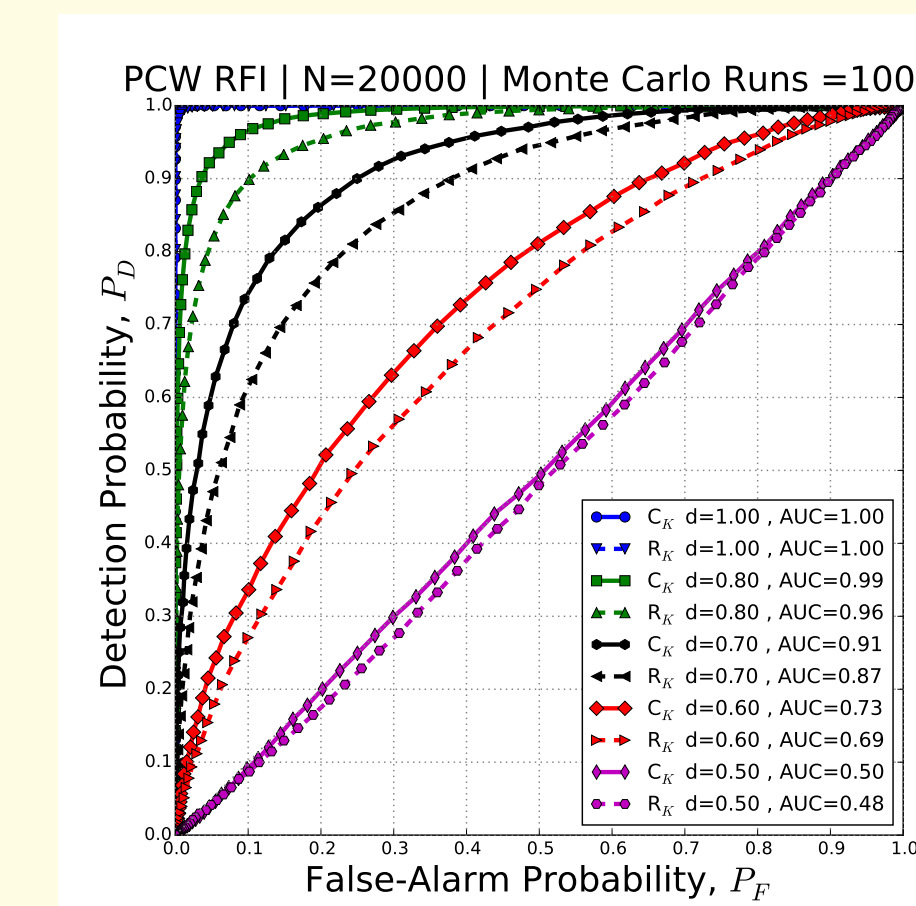


Figure 4: ROC: PCW-RFI

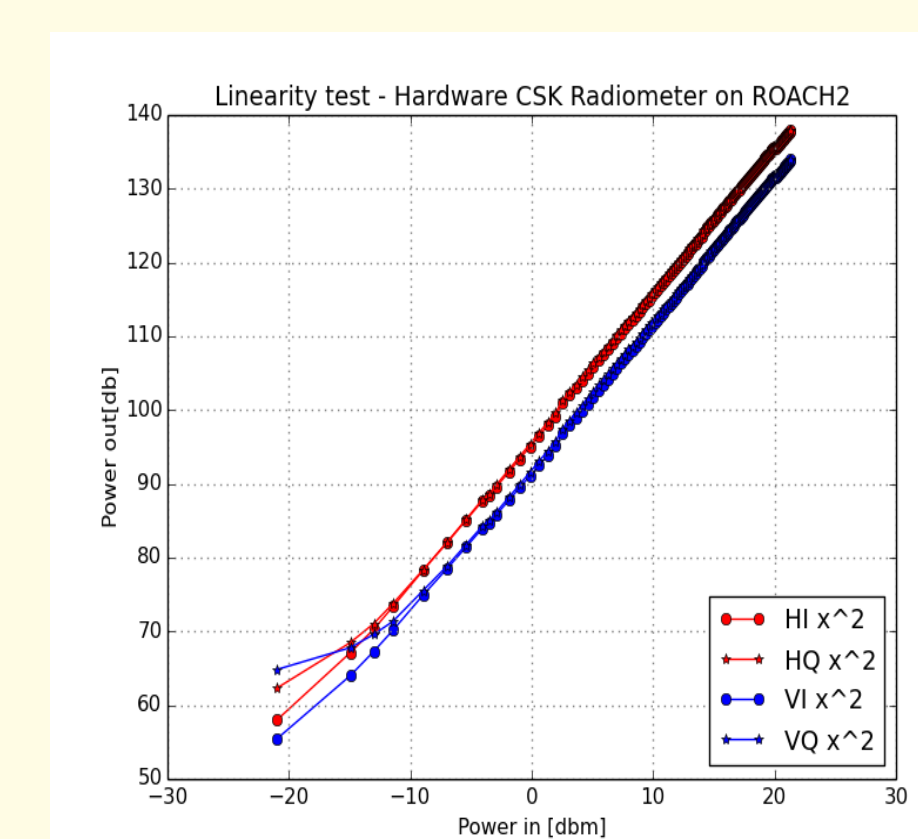


Figure 5: Linearity

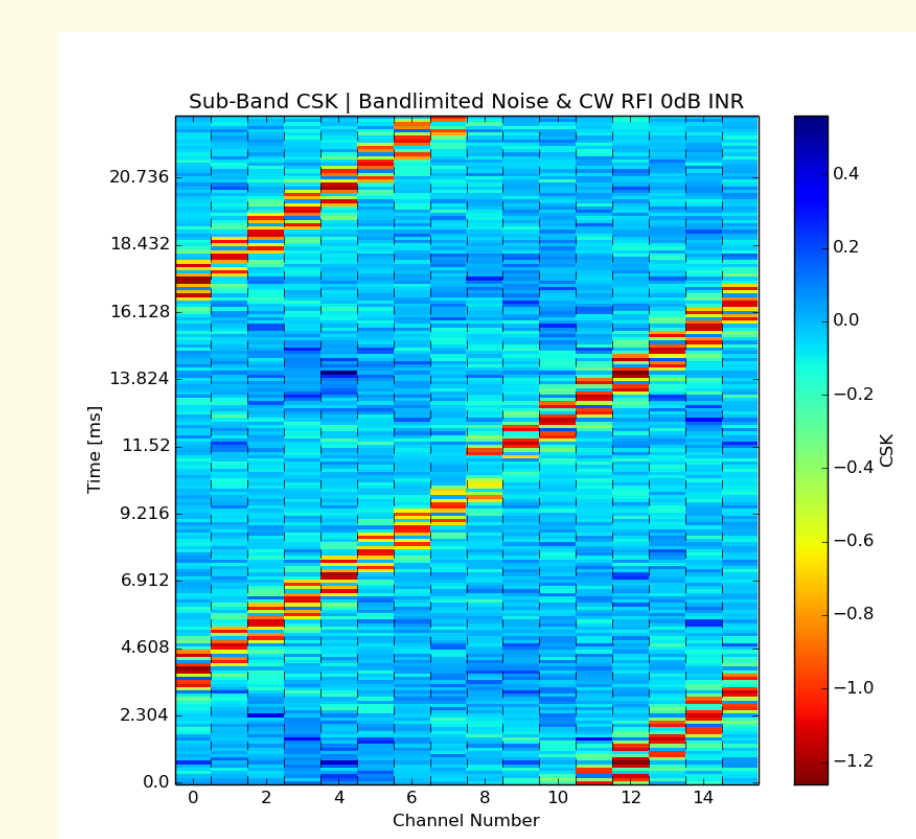


Figure 6: Subband CSK

## CONCLUSIONS & FUTURE WORK

- The CSK has a better ROC performance than the average kurtosis of I and Q component signals. It uses the natural complexity of the baseband signal to maximize detection probability.
- The CSK implemented on the WB-RFI system is ideal since the sample rate is so high. It allows for RFI detection in baseband which is also convenient for minimizing subsequent system sample rate after downconversion.
- We plan to fly this system in airborne campaigns and develop additional RFI mitigation algorithms using this platform.

## REFERENCES

- [1] J. Piepmeier, J. Johnson, P. Mohammed, D. Bradley, C. Ruf, M. Aksoy, R. Garcia, D. Hudson, L. Miles, and M. Wong, "Radio-frequency interference mitigation for the soil moisture active passive microwave radiometer," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 52, no. 1, pp. 761–775, January 2014.
- [2] D. McKague, J. J. Puckett, and C. Ruf, "Characterization of K-band radio frequency interference from AMSR-E, WindSat and SSM/I." in *IGARSS'10*, Honolulu, HI, USA, July 2010, pp. 2492–2494.
- [3] D. Bradley, C. Brambora, M. Wong, L. Miles, D. Durachka, B. Farmer, P. Mohammed, J. Piepmier, J. Medeiros, N. Martin, and R. Garcia, "Radio-frequency interference (RFI) mitigation for the soil moisture active/passive (SMAP) radiometer," in *Geoscience and Remote Sensing Symposium (IGARSS), 2010 IEEE International*, Honolulu, HI, USA, July 2010, pp. 2015–2018.
- [4] D. Bradley, J. M. Morris, T. Adali, J. T. Johnson, and A. Mustafa, "On the detection of RFI using the complex signal kurtosis in microwave radiometry," in *to appear in 13th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment (MicroRad) 2014*, Pasadena, CA, USA, March 2014.

## CONTACT INFORMATION

PI Priscilla Mohammed

Email priscilla.n.mohammed@nasa.gov